

# INTEGRATED MAGNETIC FIELD STRAP FOR SIGNAL ISOLATOR

## Technical Field of the Invention

The present invention relates to a magnetic signal isolator and, more particularly, to a magnetic field strap for an integrated signal isolator.

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## Background of the Invention

Signal isolators are typically used to isolate lower voltage circuits from relatively higher voltage circuits. For example, it is frequently desirable to isolate a group of sensors being operated in a relatively higher voltage range from processing being operated in a lower voltage range.

Transformers and optical systems have been used as signal isolators. Transformers are usually rather bulky devices when compared with other electronic components associated with integrated circuits. Therefore, transformers are provided externally of the integrated circuits with which they are used.

Optical isolation is usually accomplished by modulating the signal emitted by an optical emitting device, such as a light emitting diode, in accordance with the signal being processed. The emitting device used in such a system is positioned so that the radiation it emits strikes a detector. The output of the detector is then transferred

to a processing circuit. In systems that use plural optical isolators, it is difficult, without the use of a complicated assembly, to prevent radiation emitted by one emitter device from striking other detectors located. Therefore, only one  
5 such detector, and hence only one optical isolation device, is usually used in a single package. Optical isolation has not been integrated with electronic components.

It is known to integrate a magnetic signal isolator on an integrated circuit. A magnetic signal  
10 isolator usually involves a magnetic sensor and a strap. The magnetic sensor may comprise one or more magnetoresistors, and the strap may comprise one or more straps. The strap is coupled to the input of the magnetic isolator and generates a magnetic field in response to an  
15 input signal. The magnetic sensor senses this magnetic field and produces an output signal as a function of the magnetic field. Accordingly, the strap receives an input signal from a first circuit operating at a first voltage level, and the magnetic sensor responds to the magnetic  
20 field by producing an output signal in a second circuit operating at a second voltage level, which may be either lower or higher than the first voltage level.

The magnetic sensors of known magnetic signal isolators unfortunately sense not only the magnetic field  
25 generated by the strap, but also external magnetic fields.

As a consequence, these external magnetic fields introduce an error into the output signal of the magnetic sensor. The present invention is directed to strap and magnetic sensor arrangement that is substantially immune to external  
5 magnetic fields.

Summary of the Invention

~~In accordance with one aspect of the present invention, an integrated signal isolator has first and second ends and comprises first and second isolator input terminals, first and second isolator output terminals, first and second power supply terminals, first, second, third, and fourth magnetoresistors, and an input strap. The first and second magnetoresistors are coupled to the first isolator output terminal, the second and third magnetoresistors are coupled to the first supply terminal, the third and fourth magnetoresistors are coupled to the second isolator output terminal, and the first and fourth magnetoresistors are coupled to the second supply terminal. The input strap has at least one turn coupled between the first and second isolator input terminals. The input strap is disposed with respect to the first, second, third, and fourth magnetoresistors so that a magnetic field is generated over two of the magnetoresistors in one direction, so that a  
25 magnetic field is generated over the other two of the~~

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magnetoiresistors in an opposite direction, and so that, when  
input current flows between the first and second isolator  
input terminals, a resistance of the first magnetoiresistor  
tracks a resistance of the third magnetoiresistor, and a  
5 resistance of the second magnetoiresistor tracks a resistance  
~~of the fourth magnetoiresistor~~

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In accordance with another aspect of the present  
invention, an integrated signal isolator has first and  
second ends and comprises first, second, third, and fourth  
10 magnetoiresistors and an input strap. The first and second  
magnetoiresistors are coupled to a first isolator output  
terminal, the second and third magnetoiresistors are coupled  
to a first supply terminal, the third and fourth  
magnetoiresistors are coupled to a second isolator output  
15 terminal, and the first and fourth magnetoiresistors are  
coupled to a second supply terminal. Each of the first,  
second, third, and fourth magnetoiresistors has a long  
dimension extending between the first and second ends. The  
input strap has at least one turn coupled between first and  
20 second isolator input terminals. The at least one turn has  
a first portion running alongside two of the  
magnetoiresistors and a second portion running alongside the  
other two magnetoiresistors, and the at least one turn is  
arranged so that current supplied to the input strap flows  
25 through the first portion in a first direction between the

first and second ends and through the second portion in a second direction between the first and second ends. The first and second directions are substantially opposite to one another.

5 In accordance with still another aspect of the present invention, a method of isolating first and second circuits comprising: generating a first field across at least one magnetically responsive element, wherein the first field is generated in response to an isolator input signal  
10 from the first circuit; generating a second field across at least another magnetically responsive element, wherein the second field is generated in response to the isolator input signal from the first circuit, and wherein the first and second fields are substantially opposite to one another in  
15 direction; and, supplying an isolator output signal to the second circuit, wherein the isolator output signal is derived across the at least two magnetically responsive elements, and wherein the first and second fields are generated so that the isolator output signal is responsive  
20 to the isolator input signal that generates the first and second fields but not to an external field.

In accordance with still another aspect of the present invention, a method of making an integrated signal isolator having first and second ends comprises the  
25 following: forming first, second, third, and fourth

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magnetoresistors in a first layer of an integrated structure so that the first and second magnetoresistors are substantially aligned along a first axis, so that the third and fourth magnetoresistors are substantially aligned along a second axis, and so that the first axis is offset from and parallel to the second axis; coupling the first and second magnetoresistors to a first isolator output terminal; coupling the second and third magnetoresistors to a first supply terminal; coupling the third and fourth magnetoresistors to a second isolator output terminal; coupling the first and fourth magnetoresistors to a second supply terminal; forming an input strap in a second layer of the integrated structure so that the input strap, when receiving an input, generates a field across two of the first, second, third, and fourth magnetoresistors and an opposing field across the other two of the first, second, third, and fourth magnetoresistors; and, coupling the input strap between first and second isolator input terminals.

20 Brief Description of the Drawings

These and other features and advantages will become more apparent from a detailed consideration of the invention when taken in conjunction with the drawings in which:

Figure 1 illustrates an exemplary magnetic sensor that may be used in a magnetic signal isolator;

Figure 2 illustrates an integrated magnetic signal isolator according to one embodiment of the present invention and incorporating the exemplary magnetic sensor illustrated in Figure 1;

Figure 3 is a cross section of the integrated magnetic signal isolator taken along line 3-3 of Figure 2;

Figure 4 illustrates an integrated magnetic signal isolator according to another embodiment of the present invention and incorporating the exemplary magnetic sensor illustrated in Figure 1; and,

Figure 5 is a cross section of the integrated magnetic signal isolator taken along line 5-5 of Figure 4.

#### Detailed Description

As shown in Figure 1, an integrated magnetic signal isolator 10 according to one embodiment of the present invention includes a magnetic sensor 12 having magnetoresistors 14, 16, 18, and 20. Each of the magnetoresistors 14, 16, 18, and 20 may comprise a corresponding thin film of a magnetically responsive material, such as Permalloy or a multilayer GMR film such as Co/Cu/Co. A junction 22 between the magnetoresistors 14 and 20 is coupled to a bridge voltage supply, and a junction 24



between the magnetoresistors 16 and 18 is coupled to a reference, such as ground, of the bridge voltage supply. A junction 26 between the magnetoresistors 14 and 16 and a junction 28 between the magnetoresistors 18 and 20 provide the output of the magnetic sensor 12. As can be seen from Figure 1, the magnetic sensor 12 is arranged as a Wheatstone bridge.

As shown in Figures 2 and 3, the magnetic sensor 12 is integrated with an input strap 30 and a set-reset coil 32 to form the integrated magnetic signal isolator 10. The integrated magnetic signal isolator 10 includes a semiconductor substrate 34 over which is formed a dielectric layer 36. The magnetoresistors 14, 16, 18, and 20, which may be provided as permalloy thin films having "barber poles" on the tops thereof, or as GMR multiplayer films, are formed over the dielectric layer 36, and a dielectric layer 38 is formed over the magnetoresistors 14, 16, 18, and 20. Each of the dielectric layers 36 and 38 may comprise, for example, silicon dioxide or silicon nitride.

Barber poles are individual conductors that are deposited at an angle across the magnetoresistive material forming the magnetoresistors. These barber poles cause current to flow at an angle through the magnetoresistors. Alternatively, a Barber-pole configuration may include alternating strips of magnetoresistive material (such as

permalloy) and conductive material. The dimensions of the strips and the dimensions and orientation of the conductive material may be varied to assist in providing the desired performance characteristics.

5           The input strap 30 includes at least one turn provided on the dielectric layer 38 above the magnetoresistors 14, 16, 18, and 20. With this arrangement, when the input signal is provided to the input strap 30, current flows through the input strap 30 along the  
10 magnetoresistors 14 and 16 from an end 40 to an end 42 of the integrated magnetic signal isolator 10, and current flows through the input strap 30 along the magnetoresistors 18 and 20 from the end 42 to the end 40 of the integrated magnetic signal isolator 10, depending on the polarity of  
15 the input signal. Thus, the current flows through the input strap 30 and along the magnetoresistors 14 and 16 in one direction, and current flows through the input strap 30 and along the magnetoresistors 18 and 20 in an opposite direction.

20           A dielectric layer 44 is formed over the input strap 30, and turns of metal are provided on the dielectric layer 44 so as to form the set-reset coil 32. The dielectric layer 44 may comprise, for example, silicon dioxide or silicon nitride. As shown in Figure 2, the turns  
25 of the reset coil 32 cross the magnetoresistors 14, 16, 18,

and 20 perpendicularly. Moreover, the turns of the set-  
reset coil 32 are wound so that they cross the  
magnetoresistors 14, 16, 18, and 20 in the same orientation.  
With this arrangement, when the set-reset coil 32 receives a  
5 set-reset current pulse, the current that flows through the  
set-reset coil 32 above the magnetoresistors 14, 16, 18, and  
20 flows in the same orientation. The current could be in  
an opposite direction for half of the bridge if the barber  
pole orientation is arranged differently. The set-reset  
10 pulse is usually provided before an input is provided to the  
input strap 30 in order to preset the magnetic moments of  
the magnetoresistors 14, 16, 18, and 20 in a predetermined  
direction. This predetermined direction is preferably  
perpendicular to the fields generated by the input strap 30.

15 By presetting the magnetic moments of each of the  
magnetoresistors 14, 16, 18, and 20 in the same  
predetermined orientation, the output provided by the  
magnetic sensor 12 in response to an input to the input  
strap 30 is predictable from measurement to measurement of  
20 the output of a circuit or sensor coupled to the input strap  
30. Thus, the magnetic moments of each of the  
magnetoresistors 14, 16, 18, and 20 are consistently preset  
in the same predetermined orientation prior to each  
measurement.

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If the set-reset pulse is applied to the set-reset coil 32 such that current enters terminal 46 and exits terminal 48, a magnetic field is generated having a direction that points from the end 40 to the end 42. If the input signal is applied to the input strap 30 such that current enters terminal 50 and exits terminal 52, a magnetic field is generated across the magnetoresistors 18 and 20 having a direction that points toward a side 54 of the integrated magnetic signal isolator 10. On the other hand, this same current generates a magnetic field across the magnetoresistors 14 and 16 having a direction that points toward a side 56 of the integrated magnetic signal isolator 10.

A dielectric layer 58 is formed over the set-reset coil 32. The dielectric layer 58 may comprise, for example, silicon dioxide or silicon nitride.

With the integrated magnetic signal isolator 10 shown in Figures 1-3, a uniform external magnetic field of any direction does not contribute to the output differential across output terminals 60 and 62 coupled to the junctions 26 and 28, respectively, because the voltages across the magnetoresistors 14 and 20 produced by the external magnetic field track one another as do the voltages across the magnetoresistors 16 and 18. Therefore, any change in the

external magnetic field produces voltage changes at the junctions 26 and 28 that are equal in magnitude and sign.

However, when an input current is applied to the input strap 30, this current generates a magnetic field across the magnetoresistors 14 and 16 that is opposite in direction to the magnetic field generated across the magnetoresistors 18 and 20. These oppositely oriented magnetic fields produce a differential output across the junctions 26 and 28.

Accordingly, a magnetic signal isolator is provided that has an integrated input strap and magnetic sensor and that produces an output that is substantially immune from a uniform external magnetic field of any direction.

According to the embodiment shown in Figures 4 and 5, the magnetic sensor 12 is integrated with an input strap 70 and a set-reset coil 72 to form the integrated magnetic signal isolator 10. The integrated magnetic signal isolator 10 includes a semiconductor substrate 74 over which is formed a dielectric layer 76. The magnetoresistors 14, 16, 18, and 20, which may be provided as permalloy thin films having "barber poles" on the tops thereof, or as GMR multiplayer films, as described above, are formed over the dielectric layer 76, and a dielectric layer 78 is formed over the magnetoresistors 14, 16, 18, and 20.

The input strap 70 comprises a plurality of turns of metal on the dielectric layer 78. As shown in Figure 4, the elongated portions of the turns of the input strap 70 run parallel to the elongated portions of the magnetoresistors 14, 16, 18, and 20. Moreover, the elongated portions of the turns of the input strap 70 extend over the dielectric layer 78 and beyond the magnetoresistors 14, 16, 18, and 20. Metal traces 80 and 82 are coupled to respective ends of the input strap 70.

With this arrangement, when the input signal is provided to the metal traces 80 and 82, current flows through the input strap 70 along the magnetoresistors 14 and 16 from an end 84 to an end 86 of the integrated magnetic signal isolator 10, and current flows through the input strap 70 along the magnetoresistors 18 and 20 from the end 86 to the end 84 of the integrated magnetic signal isolator 10, depending on the polarity of the input signal. Thus, the current flows through the input strap 70 and along the magnetoresistors 14 and 16 in one direction, and current flows through the input strap 70 and along the magnetoresistors 18 and 20 in an opposite direction.

A dielectric layer 88 is formed over the input strap 70, and turns of metal are provided on the dielectric layer 88 so as to form the set-reset coil 72. As shown in Figure 4, the elongated portions of the turns of the reset

coil 72 run perpendicularly to the elongated portions of the magnetoresistors 14, 16, 18, and 20. Moreover, the elongated portions of the turns of the set-reset coil 72 extend over the dielectric layer 88 and beyond the

5 magnetoresistors 14, 16, 18, and 20. Furthermore, the turns of the set-reset coil 72 that are over the magnetoresistors 14 and 20 are wound in a clockwise direction, and the turns of the set-reset coil 72 that are over the magnetoresistors 16 and 18 are wound in a counterclockwise direction,  
10 assuming current enters the set-reset coil 72 through a metal trace 90 and exits the set-reset coil 72 through a metal trace 92. The metal traces 90 and 92 are coupled to respective ends of the set-reset coil 72.

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15 With this arrangement, when the metal traces 90 and 92 of the set-reset coil 72 receive a set-reset input, the current that flows through the portion of the set-reset coil 72 above the magnetoresistors 16 and 18 flows in a direction from the magnetoresistor 16 to the magnetoresistor 18, and the current that flows through the portion of the  
20 set-reset coil 72 above the magnetoresistors 14 and 20 flows in a direction from the magnetoresistor 14 to the magnetoresistor 20, depending on the polarity of the set-reset pulse.

If the set-reset pulse is applied to the metal  
25 traces 90 and 92 such that current enters the set-reset coil

72 at the metal trace 90 and exits the set-reset coil 72 at  
the metal trace 92, a magnetic field is generated having a  
direction that points from the end 86 to the end 84. If the  
input signal is applied to the metal traces 80 and 82 such  
5 that current enters the input strap 70 at the metal trace 80  
and exits the input strap 70 at the metal trace 82, a  
magnetic field is generated across the magnetoresistors 18  
and 20 having a direction that points toward a side 96 of  
the integrated magnetic signal isolator 10. On the other  
10 hand, this same current generates a magnetic field across  
the magnetoresistors 14 and 16 having a direction that  
points toward a side 94 of the integrated magnetic signal  
isolator 10.

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A dielectric layer 98 is formed over the set-reset  
15 coil 72.

With the integrated magnetic signal isolator 10  
shown in Figures 1, 4, and 5, a uniform external magnetic  
field of any direction does not contribute to the output  
differential across metal traces 100 and 102 coupled to the  
20 junctions 26 and 28, respectively, because the voltages  
across the magnetoresistors 14 and 20 produced by the  
external magnetic field track one another as do the voltages  
across the magnetoresistors 16 and 18. Therefore, any  
change in the external magnetic field produces voltage

changes at the junctions 26 and 28 that are equal in magnitude and sign.

However, when an input current is applied to the input strap 70, this current generates a magnetic field across the magnetoresistors 14 and 16 that is opposite in direction to the magnetic field generated across the magnetoresistors 18 and 20. These oppositely oriented magnetic fields produce a differential output across the junctions 26 and 28.

Accordingly, a magnetic signal isolator is provided that has an integrated input strap and magnetic sensor and that produces an output that is substantially immune from a uniform external magnetic field of any direction.

As shown in Figure 4, the magnetoresistor 14 has a plurality of elongated portions 104 coupled end-to-end to form a serpentine structure. The elongated portions 104 of the magnetoresistor 14 are parallel to an axis extending between the ends 84 and 86. Each of the other magnetoresistors 16, 18, and 20 has a similar construction. Moreover, the first and second magnetoresistors 14 and 16 are aligned along a first axis that extends between the ends 84 and 86, and the third and fourth magnetoresistors 18 and 20 are aligned along a second axis that extends between the

ends 84 and 86. These first and second axes are parallel to and offset from one another.

Modifications of the present invention will occur to those practicing in the art of the present invention.

5 For example, the magnetic fields that are generated by the input straps 30,70 across the magnetoresistors 14 and 16 is opposite in direction to the magnetic fields that are generated by the input straps 30,70 across the magnetoresistors 18 and 20. However, opposing fields could  
10 be applied to any combination of the magnetoresistors 14, 16, 18, and 20 by suitable re-arrangement of the input straps 30,70 and the set/reset coil. Thus, the magnetic fields that are generated by the input straps 30,70 across the magnetoresistors 14 and 18 may be opposite in direction  
15 to the magnetic field that are generated by the input straps 30,70 across the magnetoresistors 16 and 20, or the magnetic fields that are generated by the input straps 30,70 across the magnetoresistors 14 and 20 may be opposite in direction to the magnetic fields that are generated by the input  
20 straps 30,70 across the magnetoresistors 16 and 18. By suitable altering the barber poles orientation and the set/reset direction in the AMR film and altering the pinning layer and free layer magnetization directions in the GMR films in the magnetoresistors 14, 16, 18, and 20, the output  
25 across the junctions 26 and 28 will track the current

through the input strap 30. Accordingly, the configuration of the barber poles orientation in the AMR films relative to the set/reset direction and configuration of the input strap/magnetoresistor relationship must be such that the  
5 change in resistance of the magnetoresistor 14 tracks the change in resistance of the magnetoresistor 18, and such that the change in resistance of the magnetoresistor 16 tracks the change in resistance of the magnetoresistor 20.

Accordingly, the description of the present inven-  
10 tion is to be construed as illustrative only and is for the purpose of teaching those skilled in the art the best mode of carrying out the invention. The details may be varied substantially without departing from the spirit of the invention, and the exclusive use of all modifications which  
15 are within the scope of the appended claims is reserved.